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NASA SPACE COMMUNICATIONS PROGRAM

REPORT

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*On assignment to Budget Committee for 97th Congress.

LETTER OF SUBMITTAL

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C., February 1982.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology

DEAR MR. CHAIRMAN: The Subcommittee on Space Science and Applications held two days of hearings in July 1981 to explore issues associated with the NASA space communications program. The hearings provided a forum for industry and NASA officials to express their views on NASA's role in space communications, particularly in the 30/20 Gigaherty (GHz) research and development (R&D) program.

The key issues that were addressed by witnesses during the hearings were: what is NASA's appropriate role in space communications R. & D. as perceived by a carrier, a satellite builder, and how should NASA plan now for space communications beyond 1990; and what is the most effective way that NASA can distribute public information concerning the space communications program.

This document reflects the continuing interest and concern of the Committee in NASA's role in space communications R. & D. Many have contributed to the development of this report; Mr. J. Jeffrey Irons of the Committee staff played a key role in its development. The witnesses have done much to better define the needs and issues associated with the NASA space communications program.

This report summarizes the testimony, which is published as a separate document, and offers findings and recommendations based on the testimony.

Sincerely,

RONNIE G. FLIPPO,
Chairman, Subcommittee on Space Science and Applications.

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Findings and Recommendations

FINDING NO. 1

No single private company can afford to finance the large capital outlays nor bear the high risks that broad-scale space communications R. & D. efforts require. This is not to say that private industry has not in the past and will not in the future engage in significant R. & D. Unlike NASA's R. & D., industrial research and development is product- or service-oriented. At this point in the development of 30/20 GHz technology, there appears to be too many technical uncertainties and too much financial risk for private industry to undertake a 30/20 GHz demonstration program.

FINDING NO. 2

NASA's space communications R. & D. has been successful. NASA's work from 1960 to 1973 provided the basic R. & D. on which low-risk commercial systems could be developed in the private sector. These commercial systems, in turn, provide services to millions of people throughout the world. Furthermore, the success of U.S. firms in the satellite communications industry have given the U.S. a strong lead in this important segment of business. This lead is now threatened by increased foreign competition.

FINDING NO. 3

The private sector should continue to be invited to participate in shaping the direction of NASA's work in 30/20 GHz R. & D. Participation by users in these experiments is essential in order to develop user acceptance and demand, and to demonstrate mission cost-effectiveness. Only such demonstrations can provide the commercial communications satellite industry with reasonable assurance of potential economic payoff and thus encourage the implementation operational service on a timely basis.

FINDING NO. 4

Without the continuation of a strong Federal R. & D. program, dominance by foreign countries of the strategic multi-billion dollar international communications satellite market of the 1990's is likely. The sale by U.S. manufacturers of $14 to $20 billion worth of satellite communications equipment has obvious balance of payments benefits. If the U.S. buys its 30/20 GHz equipment from abroad, then there could be an outflow of as much as $10 to $15 billion from the U.S. during the 1990 to 2000 period for equipment purchases.

Recommendation:—The Federal Government should continue high-risk, long-term, and expensive R. & D. activities that will not likely be undertaken by private industry. Foreign competition in space communications is subsidized by their respective governments, and the Federal Government should continue R. & D. activities to guarantee the U.S. a substantial portion of the future space communications market.

FINDING NO. 5

A private consortium of satellite carriers and builders to share the developmental costs of the 30/20 GHz R. & D. program is a possible alternative. Witnesses agreed that resolution of the many economic, corporate, and legal obstacles of such a consortium would be too involved and too lengthy a process to allow U.S. involvement in the technology development that would guarantee a 1986–88 flight demonstration of 30/20 GHz technology.

Recommendation:—The satellite carriers and builders consortium alternative should receive further consideration by industry and the government for future space communications research and development activities.

Future Subcommittee Action

The Subcommittee on Space Science and Applications intends to hold further hearings on space communications. After reviewing testimony from the various witnesses who testified in July, the Subcommittee Members believe that there are still a number of unresolved issues:

(1) Why can't the multibillion dollar communications industry afford its own R. & D.? Some in the communications business who believe that if a tax were levied on the ultimate user, broadcasters or individual receivers, the money collected could be used to fund future R. & D. activities.

(2) Could a consortium of companies be established in a manner that would solve or avoid the problems described by the witnesses; i.e., antitrust laws and organization and governance of the consortium? It is possible that legislation could solve many such problems.

(3) If NASA discontinues or serverely curtails its 30/20 GHz R. & D., who will perform the advanced communications R. & D. necessary to complete this project?

Finally, there is a generic problem that has not been explicitly addressed. How will industries such as the space communications industry generate enough savings to fund R. & D. for the second and third generation technologies, e.g. communications satellites beyond 30/20 GHz? This problem is not unique to the communications industry, but also arises with respect to other industries that utilize technologies developed in aggressive, federally-funded R. & D. programs. This Subcommittee intends to address these issues in future hearings.

CHAPTER I.—INTRODUCTION

At the start of space exploration, relatively little was known about the extreme environment of space and life expectancy of satellites, but the R. & D. effort carried out by the National Aeronautics and Space Administration (NASA) in the early 1960's reduced the technological risks faced by the fledgling satellite communications industry and its customers. For example, NASA's Syncom II satellite accelerated technology growth and answered many questions about propagation delay, station-keeping and attitude control, reliability, and life expectancy of communications satellites. It also laid to rest doubts about the capability of launch vehicles to reach geosynchronous orbit. Since that time, the communications satellites supplied by U.S. industry have provided the U.S. with a substantial competitive lead in this market over other nations; this lead is now being threatened.

NASA's active role in satellite communications continued in high gear through the middle 1960's and early 1970's. Seven NASA satellites demonstrated various innovations, including communications to mobile receivers and TV broadcasting to small portable earth terminals. In 1973, the NASA program in satellite communications technology was phased down based on the belief that the private sector would carry on the technical development. The communications industry made noteworthy progress on its own: the number of circuits per satellite was increased, satellite weight per circuit was decreased, antenna design was improved, cross polarization achieved frequency reuse and multiple access to a satellite was achieved. As noteworthy as these advances are, industry was willing to undertake them because they offered (1) a modest risk for the development cost, and (2) a relatively quick market payoff.

In the mid-1970's, the U.S. telecommunications industry faced an uncertain regulatory future. There was concern that a company investing substantial funds in technological development might not be able to recoup the funds through subsequent operations. The result was a call for NASA to resume its sponsorship of high-risk technical development projects.

Consequently NASA has established a research and development program to assure the availability of adequate and affordable satellite communications beyond 1990. NASA's research in the 30/20 Gigahertz (GHz) frequency offers potential relief from the orbit and frequency congestion that growth in satellite communications has created.

The Subcommittee on Space Science and Applications conducted two days of hearings on the NASA space communications program. The purposes of the hearings were to: (1) describe the NASA space

communications program (the 30/20 GHz program in particular); (2) review NASA's role in the 30/20 GHz program as perceived by a satellite builder and a satellite carrier; (3) determine how NASA should plan for space communications beyond 1990 and; (4) decide how best to distribute public information about the 30/20 GHz program.

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Chapter II.—Summary of NASA Current Communications R. & D. Program

To provide an appropriate perspective, NASA provided the following summary of the present space communications research and development program:

NASA developed the first successful Earth Synchronous Communications Satellite, Syncom II, in 1963, and thus pioneered communications satellite developments. Syncom II accelerated technical growth and answered many questions about propagation delay and life expectancy of communications satellites. Next in the series of U.S. communications satellites were the Applications Technology Satellites (ATS), which initiated aeronautical and maritime satellite communications, the first TV broadcasts from satellites to many small Earth terminals, intersatellite links, and extensive propagation experiments. With the Communications Technology Satellite (CTS), a joint program with Canada, NASA pioneered satellite broadcasting in a new band (12 GHz), which has since been adopted internationally.

Satellite communications have proven to be popular and effective, and the geostationary orbit now supports over 100 foreign and domestic communications satellites. In the portion of the geosynchronous orbit serving the U.S. and Canada there are now 14 commercial satellites. These satellites are currently spaced approximately 4° apart in the orbital arc so that their Earth Station antennas can communicate with a designated satellite without interference from its neighboring satellites. Even if spacing were decreased to 3°, the new satellites now under construction would exhaust the geostationary orbit capability at the most popular band, 6/4 GHz, by the mid-1980's. The other band now in commercial use, the 14/12 GHz band, will probably be saturated over North America by 1990.

NASA's current efforts in satellite R. & D. are in the development of the third allocated band, 30/20 GHz, and of frequency reuse techniques for all bands. If successful, these developments could provide growth capability in the geostationary orbit for the next twenty years.

As discussed above, the frequency allocations for satellite communications include three major bands. The 6/4 GHz band is the most popular one and is used on all of the 40 International Telecommunications Satellites (INTELSATs) which have been launched as well as on 13 of the 14 North American domestic satellites currently being used. Equipment to operate in this band is widely available, and operations are rarely affected by precipitation. However, disadvantages of the 6/4 GHz band are that it shares the frequency allocation with terrestrial microwave radio relays, and that the antennas cannot readily be located in metropolitan areas.

The 14/12 GHz band has only recently been used commercially. Although "outages" in heavy rainstorms occur more frequently at 14/12 GHz than at 6/4 GHz, antennas can be located on roof-tops and in parking lots of factories and office buildings. While INTELSAT and some domestic satellites have used both 6/4 and 14/12 GHz bands on their satellites, some of the newer domestic satellites use 14/12 GHz exclusively.

The 30/20 GHz band operates in the millimeter wave portion of the spectrum, which is now relatively free of radio interference. It also can provide five times the capacity (bandwidth) of either of the two lower bands. However, it is more susceptible to interruptions during rainstorms, and off-the-shelf hardware is currently unavailable.

In 1978, NASA contracted with two communications common carriers to conduct market studies to determine if and when communications capacity beyond that available from current technology satellites would be needed. These studies concluded that satellites would saturate available capacity by 1990. Since completion of these studies, additional allocations have been provided, but satellite traffic growth has exceeded expectations, and saturation over North America is now likely to occur earlier than 1990.

System designs have been conducted by all U.S. commercial satellite manufacturers. These designs have demonstrated that communications in the 30/20 GHz band are feasible, and have helped identify the needed critical technology.

TECHNOLOGY DEVELOPMENTS

NASA has initiated an industrial program to generate technological advances that are essential to the effective utilization of the 30/20 GHz band. This program includes the following components and subsystems:

Spacecraft Transmitters to operate at 20 GHz are needed, and advanced technology development is under way on three types. These include a 75 watt traveling wave tube, capable of high output power and 10-year life, and two types of solid-state amplifiers.

Spacecraft Receivers to operate at 30 GHz are under "proof of concept" development at two contractors. These sensitive receivers are expected to have the capability to detect signals as low as 5 dB (decibels) or less.

The spacecraft antennas technology development underway includes multiple beams which can re-use the allocated frequencies in adjacent beams. Previously developed spacecraft, such as the INTELSAT V, have used as many as six beams. These beams had relatively large "footprints" on the Earth's surface, and had wide separations between them to avoid interference. A 30/20 GHz spacecraft antenna can be designed to operate in two modes, a trunking mode to cover major cities in the U.S., and a customer premise service (CPS) mode to cover about 20 percent of the remainder of the U.S., in sequence. The successful development of these antennas would permit multiple re-use of the allocated band. The techniques developed here could also be adapted to future satellites operating at other bands. The CPS mode would use the beams to hop sequentially to illuminate the "footprint" area. The up-link (Earth-to-Space) would

"burst" signals intended for the Earth stations in the footprint area. Unlike previous communications satellites, which use a "bent-pipe" mode of simply shifting the frequency of all received signals and retransmitting them immediately, the 30/20 GHz satellite would store, route, and forward all incoming signals. This requires extensive on-board switching and modulating equipment.

A matrix switch can be designed to route traffic between the four active trunking beams. Although this would require only a 4x4 matrix switch, two contractors are involved in advanced technology development for matrix switches which can be expanded to 20x20.

A baseband processor can accept incoming signals, sort out the destinations of each individual signal, store it, and retransmit it at the time the antenna beam illuminates its destination. The demonstration and re-modulation of each signal can permit improvements in the signal-to-noise ratio and compensation for fading in rain-affected areas, and can accommodate rapid changes in traffic patterns. This could be the most difficult technical challenge in the 30/20 GHz technology development.

Earth station developments will include ground based transmitters operating at 30 GHz, receivers operating at 20 GHz, and means to compensate for fading caused by rainfall.

All of the technology contracts currently underway are intended to deliver "proof-of-concept" models which can be functionally tested in a laboratory. These tests are intended to reduce the risk of experimental flight models which use these, or similar subsystems.

Intersatellite links

The current practice of communications satellite carriers is to design networks of Earth stations to operate with each satellite. This system would be far more versatile if an Earth station could access any other Earth station even though they were operating with separate satellites. The means to effect this would involve inter-connection between satellites. Allocations have been made for inter-satellite links, using frequencies which do not penetrate the atmosphere. NASA is planning development of equipment and techniques to permit side-band intersatellite communications at 60 GHz.

SUMMARY

The 30/20 GHz program has been formulated in cooperation with U.S. industry. A Space Applications Board Subcommittee headed by Dr. John Harrington, Director of Comsat Laboratories, and including representatives from satellite manufacturers, carriers, and users, has helped define the program. A working group composed of representatives from all satellite carriers has formulated an Experiments Plan.

The next logical step for a 30/20 GHz program would be a flight experiment to validate the technology. U.S. carriers would be the principal experimenters, and would be expected to provide their own Earth station networks and operating personnel.

Chapter III.—Summary of Hearings by Witness

This section presents a summary of the testimony of each witness who appeared before the subcommittee in the order of witness appearance. In all cases the following abstract is a staff prepared summary of the verbal and written testimony presented.

Dr. Anthony J. Calio, Associate Administrator for Space and Terrestial Applications, National Aeronautics and Space Administration, accompanied by Mr. Robert T. Lovell, Director, Communications and Information Systems Division reviewed how NASA initiated the communications research and development program:

Following the opening of the space age by the Soviet Union's Sputnik satellite in 1957, NASA sponsored a series of experimental space communications projects such as Echo, Relay, and Syncom in the early 1960's. The propulsion, spacecraft, and Earth-station technologies that make today's satellite communications possible resulted from this early work. In particular, the successful demonstration of Syncom II settled the debate over the usefulness of the geosynchronous orbit versus the low-altitude orbit for space communications, and the real commercialization of space communications began.

Dr. Calio also described the characteristics and differences between the C-band (6/4 GHz), Ku-band (14/12 GHz), and Ka-band (30/20 GHz); and he explained the capacity capabilities of the 30/20 GHz spectrum:

The amount of the frequency spectrum (bandwidth) allocated for satellite communications is 800 MHz at C-band, 500 MHz at Ku-band, and 2500 MHz at Ka-band. Since bandwidth is a first order measure of communications capacity, Ka-band offers approximately twice the combined capacity available in C- and Ku-bands. It is a primary motivation of the 30/20 GHz technology effort to bring that very large capacity within the reach of commercial communications satellite operations.

He also reviewed NASA's progress in space communications through 1973, and the progress made by private industry following the 1973 peak funding of the Communication Technology Satellite (CTS):

NASA sustained a strong program in satellite communications technology development through the middle 1960's and early 1970's. Six experimental applications technology satellites (ATS) and one experimental communication technology satellite (CTS) were developed and launched. These systems demonstrated several innovations including electronically despun antennas, VHF and L-band communications to aircraft and ships, repositioning and station-keeping in geostationary orbit, direct-to-home television broadcasting, and a wide range of component and subsystem technology improvements.

In 1973, after the peak funding for CTS was over, the NASA program in satellite communications technology was phased down, based on the belief that the maturing private sector should carry on necessary future development. From that time, the communications industry did indeed make useful progress: the number of circuits per satellite increased; satellite weight per circuit was decreased; antenna design was improved; frequency reuse was achieved through cross-polarization, and demand-assignable access and time-division multiple access to satellite were also demonstrated.

Dr. Calio discussed how NASA advanced communications R. & D. slowed between 1973-1979 while Japanese and European efforts and funding accelerated. U.S. industrial studies also indicated the demand by the year 2000 would substantially exceed supply of available transponders. Studies also predicted that sales of new communications satellites and related ground terminal equipment would total $43 billion by the year 2000; one-half of this investment will be required by the U.S. The impact of these studies and encouragement from over 100 private and Government entities dictated that NASA again become involved in development of satellite communications:

Continued NASA support of 30/20 GHz technology development was endorsed by representatives of all of these groups and became the principal element of NASA's continuation in satellite communications R. & D. in 1978.

Dr. Calio concluded:

NASA selected the 30/20 GHz advanced communications technology program as its focus, and this decision was reached primarily in response to inputs from industry. The primary objective in selecting this particular program was to provide U.S. leadership in space communications technology and also to try to conserve spectrum space.

Mr. Donald B. Nowakoski, Government Systems Division, Western Union Telegraph Company, accompanied by Mr. John Spirit, Division Vice President of Government Systems Division, Western Union Telegraph Company presented the views of their company as a satellite carrier:

The launch of Westar I (in 1974) culminated many years of intense study of the viability of such a satellite-based adjunct to Western Union's terrestrial facilities. A critical consideration was the ability of such a space-based system to perform as designed for the period of time necessary to produce the rate of return on investment required to justify the high capital investment.

In this case the largest risks came in the area of launching, orbit injection, stationkeeping, propulsion lifetime and battery life.

Mr. Nowakoski believed that there are numerous ways to fully exploit the C- and Ku-band with frequency reuse and denser orbital packing, however, this only postpones orbital and frequency saturation:

The accepted scenario indicates that despite all innovative efforts at frequency reuse, beam forming, information and signal processing, saturation at C and Ku will occur in the 1990–2000 time frame.

It is therefore imperative that technology must be available to permit carriers to plan relatively low-risk system configurations which will be economically viable with enough lead time to meet the service demand.

Therefore, it is important to initiate an aggressive R. & D. 30/20 GHz program:

The implication is that if the U.S. is not in a position to satisfy domestic telecommunications demand during the latter 1990's with an operational Ka-band satellite system, that void will most likely be filled by suppliers from other nations. There is, consequently, some urgency for NASA to move ahead with development of Ka-band technology to meet the competitive challenge in the 1990–2000 period.

The unprecedented success of present domestic satellite systems (C and Ku) can only be attributed to the fact that the technology was developed as a result of Government R. & D. efforts dating from the 1950's.

From this it seems most appropriate that the Government undertake the development of high-risk technology and demonstration of that technology in an appropriate environment. It should be noted that Western Union has and

will continue to apply whatever resources it can to support these efforts. We have, for example, offered to provide Earth stations as part of the 30/20 GHz flight test program.

In closing, Mr. Nowakoski stated:

If at that point in time the necessary technology is not available domestically, but is available from foreign sources, we may be required to acquire from those sources.

Dr. John Keigler, Manager, Communication Satellite Systems, RCA Astro-Electronics accompanied by Mr. Anthony Manna, Manager, NASA Market Development, RCA Astro-Electronics testified on NASA's R & C. role in space communications as perceived by a satellite builder. Dr. Keigler felt it important to resolve two issues:

Why should NASA conduct an R. & D. program which will primarily benefit private industry?

Why is flight demonstration required at this time?

The assumption that industry alone could support all further space communications development without NASA participation has proven in retrospect to be unsupportable for two reasons: the very high cost of total system verification, including in orbit tests, and the competing activity of foreign government-supported activity.

Dr. Keigler went on to justify why NASA's involvement in R. & D. would benefit private industry:

Most of our companies do, of course, spend a portion of their R. & D. budgets on high-risk projects, some perhaps with only generally defined goals, but the combination of very high cost with high technical risk is outside the bounds of any single aerospace, electronics, or carrier corporation. This is a combination that can only be addressed by the Federal Government through its cognizant agency, NASA. This thesis that NASA's participation is necessary for continued progress in space communications was presented in the position paper by the Electronic Industries Association in 1974, identified in one of the footnotes of my text. The first of several responsible papers advocating NASA's resumption of space communications development, it said in part: "* * * this role should encompass the aspects of space communications development and orbital tests which pose long-term benefits to the country but which are beyond the scope of private industry."

A 30/20 GHz flight demonstration program is necessary because:

The potential of similar returns from further technology development and new flight programs justify continued NASA activity in space communications in accordance with NASA's charter to advance the state-of-the-art and promote utilization of space technology.

Failure to continue through to flight demonstration would leave such technical and financial risks that even this strong new industry could not exploit the promising new technology. Moreover, foreign competition will assert itself if the U.S. technological lead is lost for lack of adequate R. & D.

NASA should perform those areas of space communications research that combine high cost and high risk; prime technical examples are the 30/20 GHz program, mobile communications including search and rescue, and high power transmission.

The current NASA R. &. D. program for 30/20 GHz can only be considered adequate if it includes a flight demonstration phase to satisfy common carriers that the operational phase will be sufficiently low risk.

Dr. John V. Harrington, Senior Vice President and Research and Development Director, COMSAT Laboratories commented on U.S. and foreign competition in space communications:

Where we once were the only free world supplier of satellite launch facilities, Japan and the European Space Agency now have launch capabilities.

The Intelsat V series contracts demonstrate the extent of foreign capabilities. Ford Aerospace and Communications Corporation, the prime contractor, let some $55 million in Intelsat V subcontracts, all to non-U.S. competitors—Mitsubishi in Japan, Britian's GEC-Marconi, Selenia in Italy, France's Societe Nationale Industrielle Aerospatiale and Thomson-CSF, and Germany's MBB.

These non-U.S. awards totaled 22 per cent of the work. Until Intelsat IV non-U.S. participation never exceeded 5 percent of the total delivery prices and before the Intelsat V contract, the highest non-U.S. awards totaled $23 million.

Dr. Harrington, while looking at the communications market, stressed the importance of NASA's involvement in high risk R. & D.:

I might add parenthetically that the international traffic is increasing at the rate of about 20 percent per year, which means that every 4 years it doubles, which has great implications on the need for more communications satellites of greater sophistication. We anticipate the need for more spectrum and techniques for improving the spectrum utilization and so on.

Programs of this magnitude—experimental programs of this magnitude cannot be supported by the private sector. Only the Federal Government can sponsor the type of long-term, high-risk programs needed to maintain U.S. leadership in communications satellite R. & D. Thus, the reentry of NASA into communications satellite R. & D. is the first step toward asserting U.S. leadership in this field.

For these reasons, NASA's 30/20 GHz program aimed at developing techniques for using higher frequency bands and for achieving more efficient use of the frequency spectrum as a whole is of critical importance to the future of commercial communications satellites. This research is properly within the responsibility of the Federal Government, since the program does not duplicate the efforts of the private sector, but rather addresses only those areas that are beyond the current sponsorship capability of U.S. industry.

In conclusion, Dr. Harrington stated:

In these times of fiscal restraint, it is important to insure that short-term economic goals do not jeopardize those activities of the Federal Government which serve to maintain U.S. leadership in space communications and benefit our balance of payments.

Dr. Elizabeth L. Young, President, Public Service Satellite Consortium commented on how NASA's R. & D. effort in space communications affects public service:

We perhaps have a slightly different perspective than other witnesses who have appeared, because we are neither carrier nor manufacturer. Rather, we are a consortium of members, and we provide services to them and to others regarding the uses of communications satellites and related technologies.

Our estimates are that in the public service sector alone, requirements for transponders will more than triple between present use and what will be needed by the mid-1990's. And despite best projections, recent experience has indicated that projections, in general, underestimate the need.

As a means to share development costs of a 30/20 GHz demonstration project the possibility of a consortium between industry and NASA was proposed:

I think, in theory, any kind of consortium effort is possible in industry, but part of the problem here is we are talking about such a rigorous time frame, that to make that possible and perhaps to overcome even the possibility of certain antitrust difficulties, might preclude the very timetable that many of us feel is important in the 30/20 GHz program; namely, a flight test by probably the late 1980's, preferably 1987, so that U.S. industry is ready and able to produce commercial spacecraft by the mid-1990's.

At present, the United States is the only country in the developed world where there is even a question about the appropriate role of government in fostering space technology development.

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In countries like Canada, France, West Germany, and Japan, the necessity for a government-industry partnership is not only taken for granted, but actively supported on both sides.

And one of the key roles for the government partner is risk taking in the development of new and improved technology.

Specific areas of public service that are affected by space communications:

For specific targeted audiences, such as health, and medical services, continuing education for professionals, and emergency and early warning notification, a combination of fixed satellites at 30/20 GHz, in combination with low-power TV and cable, where available, would seem more economical and efficient.

I think it may be useful to add a note at this point about the interrelationship between satellite communications, travel, and energy resources. There has still been insufficient use of communication satellites for such business practices as to give us substantially accurate estimates of how much in travel and travel-related energy costs we might save by substituting improved communications.

On the order of 5 to 15 percent of travel-related costs could be saved or replaced by communications.

In practice, in our work, we are finding that while decision-makers will find travel a necessity, some kinds of travel can be curtailed, and combinations of effective communications used in conjunction with travel can give the business or public service agency more efficiency and effectiveness.

Dr. Young stressed the necessity for an immediate decision on proceeding with the 30/20 GHz program:

It is imperative that NASA work toward a launch of an experimental demonstration spacecraft in 1987. The satellite could then, with a minimum 2-year life, provide an in-orbit verification of all the relevant technology in time for industry to incorporate this technology not only in on-going plans for C-band and Ku-band satellites but in time to gear up for 30/20 GHz commercial spacecraft production.

The delicate balance of communications satellite supply and demand could be seriously thrown off if NASA is not allowed to go ahead with their proposed timetable.

What will happen if there is a delay—or worse, if there can be no flight program? It has been stated by some that the United States will be forced to buy 30/20 GHz technology from the Japanese or Europeans. This is true, but overlooks the equally disturbing fact that these countries are apparently not developing the technology with sufficient concern or spectrum conservation. So in one sense, the hardware may be available, but the spectrum congestion problem could recur in fairly short order.

Dr. Young concluded her statement by stressing the importance of the NASA/industrial partnership:

We have a commedably diverse, competitive industrial complex in this country that has many benefits, but it tends to militate against long-range planning and high-cost experimentation. If we can continue to have a partnership of Government and industry, specificially in this case, NASA and the aerospace carrier industry, the United States can serve its own needs and serve the world. Any shift in this relationship could have dire consequences for our ability to compete in the communications technology market and to meet the growing needs of our own business and public service communities.

Dr. David McElroy, Chairman, Technical Committee on Communications Systems, American Institute of Aeronautics and Astronautics, accompanied by Mr. Martin Newman, Director of Public Information, AIAA, and Johan Benson, Director of Washington Office, AIAA, summarized the 1976 AIAA policy paper on space communications:

In 1976, the American Institute of Aeronautics and Astronautics' first policy paper urged the reestablishment of an aggressive, federally sponsored program of communications satellite technology development and demonstration, involving

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applications-type test flights. This recommendation resulted from two major concerns that arose in the wake of NASA's disengagement from an active communications satellite research and development role. The first involved the failure of private industry to establish broad-scale development activity in this area and the second was prompted by the emergence of ambitious programs in Japan, Canada, and Europe.

Dr. McElroy went on to further discuss the two issues in detail:

In the mid-1970's, industry made some significant refinements on specific subsystems and techniques, but did not establish a broad-scale program involving the development and demonstration of advanced communications satellite technologies. The large required financial outlays and the risks involved have been cited as reasons for this situation. The same scenario can be anticipated today because a typical flight research and development program may cost in excess of $60 million per year over a 4-year period, whereas even the larger communications satellite organizations have been able to allocate only on the order of $5 to $10 million per year for their overall research and development activity.

The Institute also believes it is important for this Federal research and development activity to proceed in a timely manner, because competition involving advanced communications satellite technologies by foreign governments is keen. Japan plans to use the 30/20 GHz frequencies as well as multiple-beam antennas and onboard signal processing on its CS III communications satellite, which is to be operational in a 1985 to 1986 time period.

Similar advanced technologies are envisioned to be flown in Europe's L-SAT program and in Italy's I-TALSAT activity. Without corresponding on-orbit demonstrations and tests of our laboratory developments, there is considerable likelihood of foreign country dominance of the strategic multibillion-dollar international communications satellite markets of the 1990's.

Dr. McElroy concluded his statement with the following:

I would like to add that while I personally support the overall thrust of this administration's economic recovery plan and I recognize the need for cuts in Government spending, I do not believe that NASA plans for its 30/20 GHz technology programs should be substantially reduced at this time. The total program has a great potential for economic benefits and the preservation of the U.S. leadership in the communications satellite field.

Mr. Newman suggested how best to prepare public information concerning the 30/20 GHz program after reviewing the current published document:

Whoever is to write for the public must be a professional writer and not an engineer, and certainly not an engineer who is working on the program. In that case, familiarity with the program would presume a kind of understanding that the public simply does not have—which is what I think happened in this particular booklet.

There are two more things to consider: First, the budget. How much, exactly, is in it for this particular public campaign? Second, given the budget, what is the best way to spend it? There are a lot of choices—news releases, feature stories, lectures, shows, interviews on television and radio, distribution of printed material to the public, or some combination of any of those.

Mr. Newman concluded:

The public's intelligence must never be underestimated; the public's ability to understand technical concepts must never be underestimated. However, the public's background in technology must never be overestimated. A good public information officer knows this instinctively.

Chapter IV.—Major Issues

Foreign competition in advanced space communications R. & D.

Can the United States become adequately involved in the Ka-band market, since the Japanese already have a substantial lead in the field and have launched a system?

Dr. Calio (NASA):

Because of the greater adaptability of the spectrum-conservative technology being developed by the United States and because U.S. technology has the potential to provide service at substantial lower unit cost, if the U.S. moves promptly to meet the challenge of foreign competition, it will have the opportunity to capture and to maintain leadership in economical employment of the Ka-band spectrum.

Mr. Nowakoski (Western Union):

While the Japanese are proceeding with the launching of Ka satellites and plan to put Ka satellites into operational service, they do not now have a substantial lead in the field. I feel that it is important to understand that the Ka systems required for United States domestic service differ markedly from those optimized for Japanese service. New technology for the antenna structure, antenna feeds, on board processing, large matrix switches and most important, the systems technology, are in the earliest stages of development.

It is in these areas that United States acrospace-technology-oriented firms may gain overwhelming advantage in the late 1980's.

Dr. Keigler (RCA):

At this time, the Japanese lead in Ka-band technology is primarily in the area of microwave transistors, specifically low-noise and power types of gallium-arsenide field effect transistors of GaAs FETs. They do not presently have such a lead in sophisticated multibeam antennas, interconnecting matrix switches, baseband signal processors, and travelling wave tubes, all equally important components of a practical Ka-band satellite. Their CS satellite launched in 1977, a combined C- and Ka-band experimental satellite built under prime contract by Ford Aerospace with the Ka-band transponder furnished by Japan, is a repeater satellite. Except for the Ka-band amplifiers, it does not represent any advance over existing U.S. C- and Ka-band satellites. Therefore, continuation of the 30/20 GHz program through to flight demonstration will enable the U.S. to become adequately involved in the Ka-band market, since it will provide the other technologies in addition to microwave transistors necessary for an operational system. It is not the current Japanese lead in a single technology that is of concern, but the trend, namely, that Japan (in addition to Europe) is pursuing a vigorous program to develop Ka-band technology while the U.S. is not so committed.

Dr. Young (Public Service Satellite Consortium):

The short answer is "yes". The Japanese are still at the experimental stage. Further, the U.S. proposes to develop technology that will be more attuned to spectrum conservation.

In many other instances, it has occurred that technology development has run nearly parallel in one or more countries, and that has had the benefit of increasing efficiency through competition and ultimately broadening the world market and supply of the particular technology. While there is no certainty that the U.S. could benefit immediately from Japanese work on 30/20 GHz, there is every indication that the U.S. could benefit from its own development activities and could begin to create a supply for a broader international market.

Dr. McElroy (American Institute of Aeronautics and Astronautics):

Yes. The actual market for the extensive operational utilization of Ka-band technology is projected for the 1990's. Consequently, we should be competitive in this area by that time frame, if we maintain our present NASA initiatives including the plans for a developmental launch in the 1986–1987 time frame. After this demonstration, industry would have approximately three years to make any needed refinements and incorporate Ka-band technology into operational systems to meet the service demands of the next decade.

Due to the lack of advanced technology developments at UHF in the United States during the mid-1970's, I believe that the Japanese identified Ka-band as an area that they could possibly dominate. They have proceeded in that direction and have launched one test spacecraft (CS–1) with another to follow before the launch of an operational system in 1986. On the other hand NASA's Ka-band technology initiatives are generally more advanced than the Japanese ones. Consequently, if we maintain our momentum, we should become very competitive.

Foreign competition using U.S. developed technology.

Should the United States not disclose any research results from the 30/20 GHz program so we can have an advantage over our foreign competitors?

Dr. Calio (NASA):

Communications satellite technology is a fast paced, rapidly growing field. Any attempt to restrict disclosure of our 30/20 GHz research results intended for use in commercial systems in the world market is probably unrealistic and, in part, self-defeating. Carried to the extreme, it would require restrictions on foreign science and engineering students at U.S. universities; travel by both foreign and U.S. engineers and scientists; and participation in international projects.

Mr. Nowakoski (Western Union):

The only area, in my perception, where this knowledge can be closely held, or denied to foreign entrepreneurs, is that which is classified in the interest of national security. Our society thrives on free publication of non-classified information and I am dubious of any attempt to alter this phenomenon.

Dr. Keigler (RCA):

To the degree practical, the U.S. should exploit its research results from the 30/20 GHz program to realize advantage over foreign competitors. However, research results do eventually diffuse throughout the world so that competitive advantage is essentially only a matter of lead time. It is rather unrealistic to consider that technical results can be suppressed indefinitely. As in any other race, you must continue to run to stay ahead.

Dr. Young (PSSC):

No. This would be practically impossible under any circumstances. What would be in the best interests of the U.S. would be to have industry involved (as they are) in a continuous research program and to allow our manufacturers to develop technology that can be marketed to others seeking it.

Dr. McElroy (AIAA):

I do not personally feel that disclosure limitations are advantageous except as required for national defense purposes. They can be difficult and expensive to implement and enforce and can restrict the flow of critical information among those working on our systems. As long as we have an aggressive technology development program, I believe that we will remain competitive without having to attempt to restrict the availablility of information.

Advanced communications R. & D. and communications cost trends.

If the demand for communications satellites continues to grow, shouldn't satellite builders and carriers put a larger fraction of revenue into research and development?

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Dr. Calio (NASA):

This question could best be answered by industry; however, we feel that the communications industry in the United States is unique. It is comprised of manufacturers, communications service suppliers (common carriers), and service users. Each segment is a highly competitive, dynamic and non-monolithic structure. The benefits from research and development (R. & D.) investments in communications satellite technology accrue to all segments, but the major share goes to the service suppliers and users. These segments have little or no incentive to invest in communications technology—particularly not in the high-cost, high-risk, and long-term elements of that technology.

The satellite manufacturers can be expected to increase R. & D. investment if satellite system sales continue to increase. However, the R. & D. investment of satellite builders and carriers is likely to continue to be concentrated on lower-risk technology which offers payoffs in the near term (2–3 years) and is limited to relatively modest sums consistent with the profits generated by the sales of satellite systems.

Mr. Nowakoski (Western Union):

We plan on providing financial support to the NASA Ka initiative at the level our corporate financial posture permits. We will review our planned levels of support annually and adjust this support as dictated by the posture and maturity of the Ka initiative at that point in time, consistent with other Corporate obligations.

Dr. Harrington (COMSAT):

There is no single answer to this question because, on one hand, satellite manufacturers are probably already putting in enough of their monies into R. & D. work. On the other hand, carriers find themselves in different positions. AT&T, after having funded entirely by itself the TELSTAR programs in the early '60s, has not in its development program given great emphasis to satellite communications. Their major R. & D. effort is in the direction of fiber optics.

Dr. Young (PSSC):

Perhaps there is some confusion about where the bulk of profits from the admittedly growing communications satellite business accrues. Those who benefit most are generally not the manufacturers or carriers but rather the resalers, program syndicators and users. Thus, it is not clear that there is an incentive for manufacturers or carriers to increase substantially their R. & D. Most do make a significant investment at present. The greatest difficulty arises when an entirely new frequency band, e.g., 30/20 GHz, must be opened up. Then, the magnitude of the task cannot be sustained by the normal R. & D. carried on by industry.

Dr. McElroy (AIAA):

If a fixed percentage of revenue is allocated to R. & D. then one would expect to see satellite builders and carriers putting more into this area as demand for communications satellite service grows. However, many factors, such as inflation, rising labor and energy expenses, and competition, could force reduced allocations for R. & D. even though service demand is increasing.

Price trends for information per second.

Is the cost of communication, based on amount of information per second, increasing or decreasing?

Dr. Calio (NASA):

The long-range trend has been that the cost of communication, based on the amount of information per second, is decreasing. For example, the cost of a telephone call to Europe has decreased by a factor of approximately three since the International Telecommunications Satellite (INTELSAT) began. Each of the six successive generations of the INTELSAT satellites has provided a lower cost per voice-circuit.

The oldest domestic satellite (DOMSAT) in the United States is only seven years old, and the original generation of satellites is still operative. The cost per circuit was sharply lowered by RCA's SATCOM (1975), which incorporated 24 transponders on a Thor/Delta class launch. In the mid 1970's, the DOMSAT market was a buyer's market, and the transponders were leased for $800,000 per year. In 1979, the use of DOMSAT transponders for distribution of cable

television signals transformed the market, and in today's seller's market, transponders are leased for as much as $3 million per year.

Further generations of advanced communications satellites promise to further decrease the cost per circuit. This is especially true of satellites using the 30/20 GHz band. Although total costs may be twice conventional C-Band satellites costs, they will provide as much as ten times the circuit capability. Like INTELSAT, successive technical improvements and the greater launch capability of the Space Shuttle will continue to reduce annual circuit costs. The price of these circuits in a free market will depend on supply and demand. If the capacity for the geostationary arc available to the United States is filled, and technical solutions to overcome these limits are not forthcoming, the price of satellite circuits is likely to increase substantially.

Dr. Young (PSSC):

Generally, the cost appears to be decreasing. There are exceptions, e.g., in sparsely populated, rural areas of the country and of the world, where costs may tend to remain more constant or even, in rare instances, increase.

Dr. McElroy (AIAA):

The cost of satellite communications is decreasing significantly, even in the presence of continuing inflation. Dr. Harrington's testimony in this hearing noted that INTELSAT's annual charge for a voice grade circuit has dropped from $22,350 in 1965 to $4,680 today.

This reduction is largely due to the incorporation of advanced technologies, many of which were initially developed and demonstrated under NASA programs, so that each new generation of spacecraft offered capacity increases that exceeded its increased cost. However, such a trend cannot continue without the incorporation of new technology to utilize the higher frequencies (i.e., 30/20 GHz and beyond). Otherwise, as the C– and Ka–Bands saturate, increased demands for a limited product (i.e., capacity) will result in increased service charges, as predicted in Dr. Young's testimony.

Technology start up point for the 30/20 GHz program.

Should we take the foreign "state-of-the-art" technology in 30/20 GHz and start our program from here, or do we start from the beginning (without foreign influence)?

Dr. Calio (NASA):

Foreign state-of-the-art technology in the 30/20 GHz band includes the contoured beam spacecraft antenna, the transponder, the solid-state power and low noise amplifiers and the small Earth stations. With the exception of the Earth stations and superior performance of some foreign solid-state components, all the required technologies are available in the United States.

But the key technologies being developed in the 30/20 GHz technology program are the multi-spot beam spacecraft antenna, the on-board, high-speed matrix switch, and the baseband processor—all of which control the routing of signals. These technologies are currently unavailable from any source, foreign or domestic.

Dr. Keigler (RCA):

The diffusion of technology around the world referred to in response to the question is a two-way process. In those specific areas of 30/20 GHz development where Japan and/or Europe is ahead, U.S. industry will surely take advantage of their work rather than "reinvent the wheel". As the result of industry R. & D. and the NASA 30/20 GHz program to date, the U.S. is in fact already well past the beginning.

Dr. Harrington (COMSAT):

No. There is no need to start from the beginning. What is required is a reactivation of NASA programs which were halted around '73. We have, of course, monitored all foreign programs.

Dr. Young (PSSC):

It is our understanding that certain components of the proposed 30/20 GHz system will be available fro m abroad, but in the development of new items such as

the multi-spot beam antenna, there is nothing that the U.S. could acquire elsewhere, and it is the development of such unique technclogies that require the furtherance of a United States developmental effort.

Dr. McElroy (AIAA):

It seems to me that this question is more appropriate for a program that is not yet underway. NASA now has a focused program involving more than $10M in FY 81 expenditures for "proof-of-concept" developments of critical Ka-Band satellite items such as multiple-beam antennas, solid-state and traveling-wave-tube high-power amplifiers, low-noise receivers, switching matrices, and signal processors. I believe that most of this technology, perhaps all of it, is using U.S. developments and components. However, in carrying out this work, I would expect that our industry is drawing on those previous efforts that are appropriate, whether they be domestic or foreign.

I feel that the important issue facing this committee does not involve the type or level of technology for a U.S. 30/20 GHz program. NASA initiatives will produce competitive advanced satellite communications technology if they are adequately supported. They have been strongly endorsed by your witnesses from the spacecraft and carrier industries, the user organizations, and the technical societies. I offer that the continuance of such support to include a flight demonstration phase in a timely manner is the central issue.

Consideration of a satellite carrier and builder consortium for the 30/20 GHz program.

Do you feel that a consortium of satellite carriers and builders would be willing to invest and therefore completely fund the 30/20 GHz program? By forming a consortium, you could lower individual investments while the risk would still be high. The people who testified stated that industry does not mind small investments in high risk areas; but industry cannot afford large investments in high risk areas.

Dr. Calio (NASA):

We feel that while the formation of a consortium of satellite carriers and communication satellite manufacturers to fund the 30/20 GHz program is theoretically possible, it is beset by several major difficulties. The cost of a test and evaluation satellite is substantial and the R. & D. funds available to individual companies in the industry are typically a small fraction of the total program cost. A consortium would likely be comprised of many individual companies, with consequent difficulty in, first, securing their participation in the consortium, and then in reconciling priorities and views among consortium members. Furthermore, the corporations with the largest resources tend to be the common carriers and the non-carrier communications service suppliers, rather than the communication satellite manufacturers. The common carriers and non-carrier service suppliers have little incentive to invest in long-term, high-risk R. & D. or to commit a major part of their R. & D. funds to the consortium. They may choose to purchase from a foreign supplier.

Even if these difficulties could ultimately be resolved and a legal working agreement between the parties established, it probably could not be accomplished in time to meet the need for this technology or adequately to combat growing competition from foreign programs.

Mr. Nowakoski (Western Union):

It is Western Union's opinion that a consortium of satellite carriers and builders would not work. In today's competitive market it is difficult enough to anticipate that type of cooperative use of development resources ($'s) between carriers, much less between satellite manufacturers, broadcasters and CATV users, earth station manufacturers, etc.

How would one estimate the difficulty of determining the dollar share per member of the consortium; terms under which members would direct and/or scope such a program, and finally, how would they share in the resultant failures and/or successes? It is an interesting idea, but not workable.

Another idea was expressed by Congressman Shamansky and does, in Western Union's opinion, have merit. This idea would be to provide government support

for the 30/20 GHz program, however, the government would intend to recover these costs via common carrier satellite tariffs. It is conceivable that a total business revenue forecast could be projected for the 1990's and a built-in required tariff supplement be required from all common carriers as they implement service, utilizing the 30/20 GHz technology. That tariff dollar supplement would flow back to the U.S. Treasury.

There are many questions that can be raised regarding this idea, however, it is Western Union's opinion that such an approach seems practical. Certainly, it is more so than the consortium idea.

Dr. Keigler (RCA):

While perhaps willing in principle, the communications satellite industry is not likely in practice to be able to proceed on the required time table with a consortium for the 30/20 GHz program. Resolution of the many economic, corporate, and even legal obstacles is a more lengthy process than technology development. In light of the salient dates for the program cited in earlier testimony, namely commercial operational launch in the early 90's, operational system procurement in the late 80's, flight demonstration 1986–88, and flight demonstration procurement in 1983, it is not realistic to expect such a novel consortium to be in place in time to administer the demonstration system procurement. Since bilateral corporate venture agreements require a few years to execute, it is reasonable to anticipate that a multi-corporate agreement plus government review and/or authorization would surely extend past the timetable of the 30/20 GHz flight program.

Dr. Harrington (COMSAT):

No. A consortium of communications carriers and spacecraft manufacturers appears an unlikely venture because conflicts would exceed by far commonality of interest.

Dr. Young (PSSC):

The practicalities of this possibility outweigh any chance that it will succeed. Time, alone, would be a negative factor. It would doubtless take well over a year for the necessary legal and financial arrangements to be put in place. Secondly, some companies might abstain simply because they do not view this as the proper method to proceed with R. & D.

The industry has indicated a willingness to share certain costs, e.g., of developing their own earth stations to be used in conjunction with an experimental 30/20 GHz satellite. Thus, industry/carrier R. & D. funds will be committed. But in terms of a mutual commitment to build the spacecraft, the consortium is not a realistic approach.

Dr. McElroy (AIAA):

Although I believe that such a consortium is theoretically possible, I feel that there are a variety of potential problems associated with it. Some of these include the resolution of anti-trust issues and the coordination and focusing of the (probably) divergent desires of numerous satellite carrier and builder organizations, many of whom are now fiercely competing with each other. Since a flight demonstration program may require $60M per year (over a period of at least four years) and since the R. & D. budgets of the larger organizations are only $5-to-$10M per year (of which not all would be devoted to high-risk technology development), one is talking about forming and getting a consensus from a consortium of many firms.

I seriously doubt that such a concept can be implemented in a timeframe that will allow the uninterrupted development and flight demonstration of 30/20 GHz technology and systems concepts by 1987. And yet, such a time schedule is essential for industry to be able to make refinements and incorporate Ka-Band technology into 1990's operational systems.

Appendix A.—List of Witnesses

July 8, 1981:

Dr. Anthony J. Calio, Associate Administrator, Office of Space and Terrestrial Applications, National Aeronautics and Space Administration; accompanied by Robert R. Lovell, Director, Communications and Information Systems Division.

Donald B. Nowakoski, Director of Marketing, Government Systems, Western Union.

Dr. John E. Keigler, Astro-Electronics Division, RCA.

July 9, 1981:

Dr. John V. Harrington, Senior Vice President and Research and Development Director, COMSAT Laboratories.

Dr. Elizabeth L. Young, Public Service Satellite Consortium.

Dr. David McElroy, Chairman, American Institute of Aeronautics and Astronautics (AIAA), Technical Committee on Communications Systems; accompanied by Martin Newman, Director of Public Information, AIAA; Johan Benson, Director of the Washington Office, AIAA.

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